MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2019/2020

EOP 4076 – LASER TECHNOLOGY AND APPLICATIONS
(OPE)

3 MARCH 2020
2.30 p.m – 4.30 p.m
(2 Hours)

INSTRUCTION TO STUDENT

1. This Question paper consists of **6** pages including cover page with **4** Questions only.
2. Attempt **ALL** questions. All questions carry different marks and the distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) In your experiment, you realized that direct pumping is not possible for your experimental laser system. Identify three possible situations that can prevent direct pumping from being an effective excitation process for the laser.

[6 marks]

(b) By using a relevant equation, explain why a two-level laser system cannot have the population inversion.

[6 marks]

(c) Write a detailed derivation of the mode distributions at the mirrors for the TEM_{22} mode in terms of the transverse variables x, y, $\rho = \sqrt{x^2 + y^2}$, and w (scaling constant).

[6 marks]

(d) With the aid of suitable diagrams, explain in detail the spectral hole burning.

[7 marks]

(e) A laser rod of length 0.15m and diameter 5mm is coated with a 100% reflector at one end of the rod, and no reflector at the other end (it has an antireflection coating on that end). It operates at a wavelength of 800nm and is homogenously broadened. The upper laser level has a lifetime of 200μs. The pumping flux is such that the laser is at threshold, and the population difference between the upper and lower laser level for that condition is measured to be $1\times10^{26}\ m^{-3}$.

(i) Calculate the stimulated emission cross section of the laser.

[4 marks]

(ii) What is the intensity of the laser at the output end of the rod?

[4 marks]

Continued...

Question 2

(a) You are a laser engineer who is working on a project developing a He-Ne laser that emits only 632.8 nm output. The challenge is that one particularly strong transition at 3.39 μm competes with the 632.8 nm transition, having a common upper laser level. With the aid of a suitable sketch and proper labelling, propose a design of conceptual structure of that laser incorporating solution to the above problem, and justify your design.

[6 marks]

(b) With a suitable energy level diagram, explain why a dye laser system can be considered as a four-level system.

[7 marks]

(c) With the aid of a suitable diagram, design a mode-locking mechanism that is based on the *pump beam aperturing* effect, for use in a Titanium Sapphire laser, and explain its working principle.

[7 marks]

(d) In a team designing an Argon ion laser, you are proposing to incorporate a cooling system, and an axial magnetic field. Justify each of your proposals to your team.

[6 marks]

(e) If you were to design a solid-state laser that reached I_{sat} when pumped, and if the gain medium (a solid-state crystal) were limited to a length of 10cm, what would the minimum single-pass small-signal exponential gain ($\sigma_{ul}\Delta N_{ul}L$) have to be at line centre if the gain duration lasts only 10ns? Assume a rod diameter of 6mm and that the mirrors are 100% reflecting and coated onto the ends of the laser rod. Assume also that the crystal has an index of refraction of 2.0.

[7 marks]

Continued...

Question 3

(a) (i) Describe the physical processes which occur during surface hardening of ferrous material (4% carbon steel) using high power lasers.

[5 marks]

(ii) State the approach and requirements for obtaining the maximum the case depth.

[3 marks]

(b) (i) Discuss the circumstances when a reactive gas stream is desirable and when it is not desirable in laser cutting.

[4 marks]

(ii) Consider pure iron which has specific heat capacity $C = 435$ Jkg^{-1}K^{-1}, latent heat of vaporization $L_v = 6.8$ x 106 Jkg^{-1}, density $\rho = 7870$ kgm^{-3}, and boiling point $T_v =$ 3160 K (or 2887°C). Assume the laser beam to have a power of 1 kW and to be focused down to a spot of diameter 0.25 mm with negligible surface reflectance R_s. Calculate the scanning velocity of the laser beam v_b required to cut the iron with a thickness of 2.5 mm.

[5 marks]

Continued...

Question 4

(a) Diffraction occurs when light passes through a very small aperture. This phenomenon can be exploited to measure the flatness or waviness of a surface. With the aid of a suitable schematic, propose a setup and procedure for the measurement.

[6 marks]

(b) With the aid of a suitable schematic, propose a procedure for readout of the beat frequency of a ring laser gyroscope.

[6 marks]

(c) Consider a fibre optic gyro with a radius of 10 cm that uses a light-emitting diode (LED) with a wavelength of 633 nm. Calculate the difference, Δ in frequency between the two propagating beams for a rotation rate, ω of 0.1 rad/hr.

[5 marks]

Continued...

Appendix A

Physical Constants and Units

Constant	Symbol	Value (mks units)
Speed of light in vacuum	c	3×10^{8} m/s
Electron charge	q	1.602×10^{-19} C
Boltzmann's constant	k_B	1.38×10^{-23} J/K
Permittivity of free space	ε_0	8.8542×10^{-12} F/m
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ N/A^2
Electron volt	eV	1 eV = 1.602×10^{-19} J
Planck's constant	h	6.626×10^{-34} J·s

End of paper